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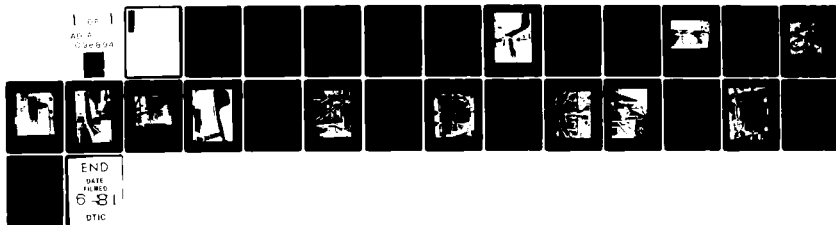
NAVAL RESEARCH LAB WASHINGTON DC
SHOCK AND VIBRATION PERFORMANCE OF WIND INDICATING EQUIPMENT, T--ETC(U)
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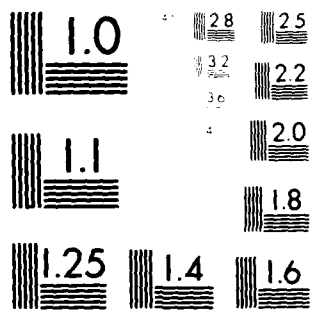
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Type F Wind-Indicating system, consisting of a wind-detector, servo-amplifier and indicator, has been subjected to shock and vibration tests in accordance with MIL-S901C and MIL-STD-167-1 Type I respectively. Various functional and structural deficiencies have been found in all three components of the system. These involve the structural design of the components, the materials from which they are made, and the fasteners which hold them together. While it is widely distributed throughout the		

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20. ABSTRACT (Continued)

\ fleet, the Type F System represents technology of World War II vintage. It is suggested that this system should be replaced by one embodying current instrumentation and measurement techniques and components which have inherently superior reliability in shock and vibration environments.

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SHOCK AND VIBRATION PERFORMANCE OF WIND INDICATING EQUIPMENT,
TYPE F.

1. Introduction.

The Type F Wind Indicating Equipment system is the fleet's current standard. Experience indicates that malfunctions and mechanical failures occur consistently in at-sea ship shock tests, and occasionally during normal operations. For the most part, these mishaps involve the detector unit. Shock and vibration tests indicate that all three units (detector, transmitter and indicator) of the system are susceptible to damage and/or malfunction under shock conditions and that the detector and transmitter units are also vulnerable to vibration. The system's performance under shock and vibration conditions could be improved by changes in design, construction and materials, but retrofit throughout the fleet would be difficult and expensive. In view of this, and the fact that the Type F system represents technology of late 1940's vintage, it is suggested that consideration be given to replacement of the Type F by a system employing more recent technology, which could be expected to be inherently more resistant to shock and vibration environments.

2. Background.

2.1. The Type F Wind Indicating Equipment system (described in Ref. 1) is comprised of three basic components -- detector, transmitter and indicator. The detector consists of a wind-vane mounted on a vertical column about whose axis it may turn freely. The column contains a 400 Hz synchro which provides a signal indicating the angle of the vane with respect to a reference direction normal to the axis of the column; when installed, the detector is aligned so that the reference direction of the column coincides (as nearly as possible) with the fore-and-aft axis of the ship. The direction synchro output thus represents the wind heading relative to the ship. The vane itself contains another 400 Hz synchro connected to an airscrew: its output is a measure of airspeed relative to the ship. The synchro outputs are fed to the transmitter, a servo-amplifier system which distributes undamped 400 Hz signals to ship's computers and damped 400 Hz and 60 Hz signals to the indicator units. The Type F Indicator units provide dial readout of wind speed and direction, and may utilize either the 400 Hz or 60 Hz transmitter outputs. The Type B Indicator may also be used with the 60 Hz output. The indicator tested here was a Type F/60 unit.

2.2. The detector is normally mounted near the end of a yardarm, the transmitter may be mounted on any convenient bulkhead, and indicators are scattered throughout the ship. This requires that each component unit be tested as an individual item, rather than together as a functional system. Accordingly, each of the three units was tested to the vibration requirements of MIL-STD-167-I Type I (Ref. 2) on the NRL 5000-lb Reaction-Drive Vibration

Machine (RVM, and to the shock requirements of NIL-S-901C (Ref. 3) on the Navy Class H.I. Shock Machine for Lightweight Equipments (LWSM) (Ref. 4). All three units were connected in their normal way, and operating during tests. Various signals were also monitored externally via pen-recorder. This was performed by NAEC Lakehurst NJ, personnel, and findings will be reported separately.

3. Shock and Vibration Tests of the Type F Detector Unit.

3.1. The shock and vibration test specifications, Refs. 2 & 3 require tests to be conducted with the excitation directed along each of the three axes of the test item aligned vertical, athwartship and fore-and-aft in its normal shipboard installation. In the case of the detector, this orientation requirement applies to the vertical column, since this part is aligned with the ship's axis and provides a reference direction for the direction synchro, and moreover has structural variations in its horizontal axes. Since the vane is free to move in response to the wind, its position with respect to the axis of excitation was considered arbitrary.

3.2. For mounting the detector, a steel pintle was made by taking a section of 1 1/16-in dia round bar stock, turning down one end for a snug fit in the socket of the detector, and welding it to a 9-in square section of 1/2-in plate drilled to match the mounting-holes of the RVM test-table. The pintle assembly was bolted to the RVM table, the detector fitted to the pintle and aligned "fore-and-aft" along the RVM table (the axis of horizontal motion), and the detector base and pintle drilled through with a 11/32-in dia drill, as described in the Type F Technical Manual. The detector was fastened with a Class 3 5/16-in dia bolt, and the split end of the mounting clamped with a pipe clamp. The completed detector assembly is shown in Fig. 1 on the RVM test table as oriented for vibration in the fore-and-aft direction. For vibration in the athwartship direction, the entire detector and pintle assembly was unbolted from the RVM table, rotated 90° and rebolted. Wind of about 6-7 kt was provided by a large fan, and directed roughly across the width of the RVM table. Its direction was approximately from port for fore-and-aft vibration, and from ahead for athwartship and vertical.

3.3. Vibration Test Requirements - The vibration test specification (Ref. 2) requires a test sequence to be performed in each of the vertical, athwartship and fore-and-aft directions of the test item. Each sequence has three parts; "Exploratory", a sweep through the frequency range at reduced amplitude to locate principal resonances; "Variable Frequency", where vibration is maintained at each integral frequency for five minutes; and "Endurance", where vibration is sustained at resonance or resonances for two hours. Test table amplitudes are specified for each band of frequencies. For mast-mounted items, the amplitudes specified for the band 4-10 Hz are much larger than for non-mast mounted items, .100 in nominal vs .030 in. It was found that the RVM was not capable of such amplitudes -- this segment of the sequence was accordingly conducted at the maximum capability of the RVM, an amplitude of about .050 in. Fortunately, all resonances were found to be above 10 Hz where the amplitudes specified for mast-mounted items are the same as for other items.

3.4. Vibration Test - Fore-and-Aft



Fig. 1 — The detector mounted on the RVM for vibration in the Fore-and-Aft axis.
It is bolted to a pintle of round bar stock welded to a 1/2-in. mounting-plate.

3.4.1. Exploratory - The RVM was operated through the frequency range 4-33 Hz at a nominal amplitude of 0.010-in, and from 34-47 Hz at an amplitude of 0.003 in nominal. A slight resonance involving the center assembly section was noted in the range 8-15 Hz; this was observed as an increase in the vibration amplitude of the lower shroud portion of the section. A similar behavior was found in the range 20-24 Hz, where there was also a noticeable increase in the vibration motion of the tail section of the vane.

3.4.2. Variable Frequency - As noted above, it was found that the RVM could not attain the vibration amplitude of 0.090-0.110 in specified for mast-mounted items over the frequency range of 4-10 Hz. Accordingly, the test over this range was conducted at an amplitude of 0.052 in, the maximum that the RVM could supply. Above 10 Hz, the test was conducted in accordance with the specifications: i.e., 11-15 Hz, 0.030 in; 16-25 Hz, 0.020 in; 26-33 Hz, 0.010 in. Vibration was maintained at each integral frequency for five minutes. The slightly enhanced motion of the center assembly section noted during the Exploratory test from 8-15 Hz no longer stood out from the generally greater motion due to the higher driving amplitude. The increased motion of the center assembly section and the tail of the vane from 20-24 Hz was observed, however, and peaked at 22 Hz, where the amplitude at the tail was about 1/4-in. The wind heading indication was affected in this range, changing from a steady 210° away from resonance to erratic readings of 170° to 200°. The detector suffered no apparent damage and functioned normally following the Variable Frequency test.

3.4.3. Endurance - The endurance test consists of a two-hour dwell at resonance. It was conducted at 22 Hz, with an amplitude of 0.020 in. After 1-1/2 hr of the test, the detector suddenly dropped out of resonance. Inspection revealed that the pintle-bolt had fractured at the first thread (i.e., closest to the head). The bolt was removed and replaced with the CRES bolt normally supplied with the detector for this application. The final 1/2 hr of the Endurance test was then completed. No damage or malfunction of the detector was observable following the test.

3.5. Vibration Test - Athwartship.

3.5.1. Exploratory - For tests in the athwartship axis, the mounting-plate was removed from the RVM table, rotated 90° and refastened, so that the normally athwartship axis of the detector's vertical column was aligned with the axis of the vibration. The relative wind furnished by the fan was not moved, however, so that the vane assembly had the same orientation to the axis of vibration which it had for the previous fore-and-aft tests. Not surprisingly, the behavior was similar. The RVM was operated over the range of 4-46 Hz, at amplitudes of 0.010 in (4-33Hz) and 0.003 in (34-46 Hz); enhanced motion of the shroud portion of the center assembly section was noted from 9-12 Hz, and of the shroud plus the tail of the vane from 20-24 Hz.

3.5.2. Variable Frequency - The RVM was operated over the range 4-33 Hz at amplitudes of 0.052 in (4-10 Hz), 0.030 in (11-15 Hz), 0.020 in (16-25 Hz), and 0.010 in (26-33 Hz), with a five minute dwell at each integral frequency. As noted in the fore-and-aft test, the slight apparent resonance of the shroud of the center assembly section at 9-12 Hz was no longer distinguishable. The general resonance of the vane, tail and center assembly section was observed from 20-24 Hz, peaking at 22 Hz. The direction reading was

erratic at resonance here also, changing from a steady 300° away from resonance to a varying 275°-295°. No damage or unusual behavior was noted following the test.

3.5.3. Endurance - The RVM was operated at 22 Hz, table amplitude 0.020 in for two hours. No unusual behavior was noted, save for the erratic direction indication noted earlier. No damage or malfunction was observed following the test.

3.6. Vibration Test - Vertical.

3.6.1. Exploratory - No changes were made in the mounting of the detector on the RVM, as the change in vibration direction from the horizontal to vertical axes is made by reorientation of the RVM's forcegenerators. The RVM was operated from 4-33 Hz at amplitude 0.010 in, and from 34-46 Hz at amplitude 0.003 in. A general resonance of the entire vane assembly was found from 9-13 Hz, comprising mostly a rocking motion.

3.6.2. Variable Frequency - The RVM was operated at amplitudes of 0.062 in (4-10 Hz), 0.030 in (11-15 Hz), 0.020 in (16-25 Hz), and 0.010 in (26-33 Hz); at each integral value of frequency vibration was sustained for five minutes. Note that in the vertical direction the RVM was capable of slightly higher maximum amplitudes. As noted in the exploratory test, a general resonance of the vane assembly was found from 9-13 Hz, peaking at 12 Hz. Again, the direction indication showed some irregular variation at resonance, changing from a steady 300° to erratic readings from 290° to 310°. No damage or malfunction was observed following the test.

3.6.3. Endurance - The RVM was operated at 12 Hz, amplitude 0.030 in, for two hours. No unusual behavior was observed save the erratic direction indications. No damage or malfunction was observed following the test.

3.7. Assessment of Vibration Performance - From a structural standpoint, the performance of the detector would appear to be acceptable: the resonance of the vane assembly appeared to cause no permanent damage or malfunction, and the pintle bolt which failed was not the part specified for the application. However, it was a high-strength bolt, and the fact that it failed gives reasons to suspect that the pintle bolt may be of marginal strength, hence a potential weak point. From an operational standpoint, the fact that the detector provides erratic and slightly erroneous direction indications when in a resonant condition may be of some concern. This would have to be determined by consideration of operational requirements.

3.8. Shock Tests - After completion of the vibration tests, the mounted detector assembly was removed from the RVM and mounted on the Lightweight Shock Machine. In discussion with NAVSEA and NAVAIR representatives, it had been decided to mount the detector on the 4A plate in order to avoid the strong rotational motion component characteristic of the shelfplate. When this was done, the detector was placed so as to align the axis of its vertical member on the axis of percussion of the swinging hammer and the back anvil pad. This arrangement is shown in Fig. 2. A reference wind was again provided by a large floor fan.

3.8.1. Back Blows - In this orientation, the reference wind direction

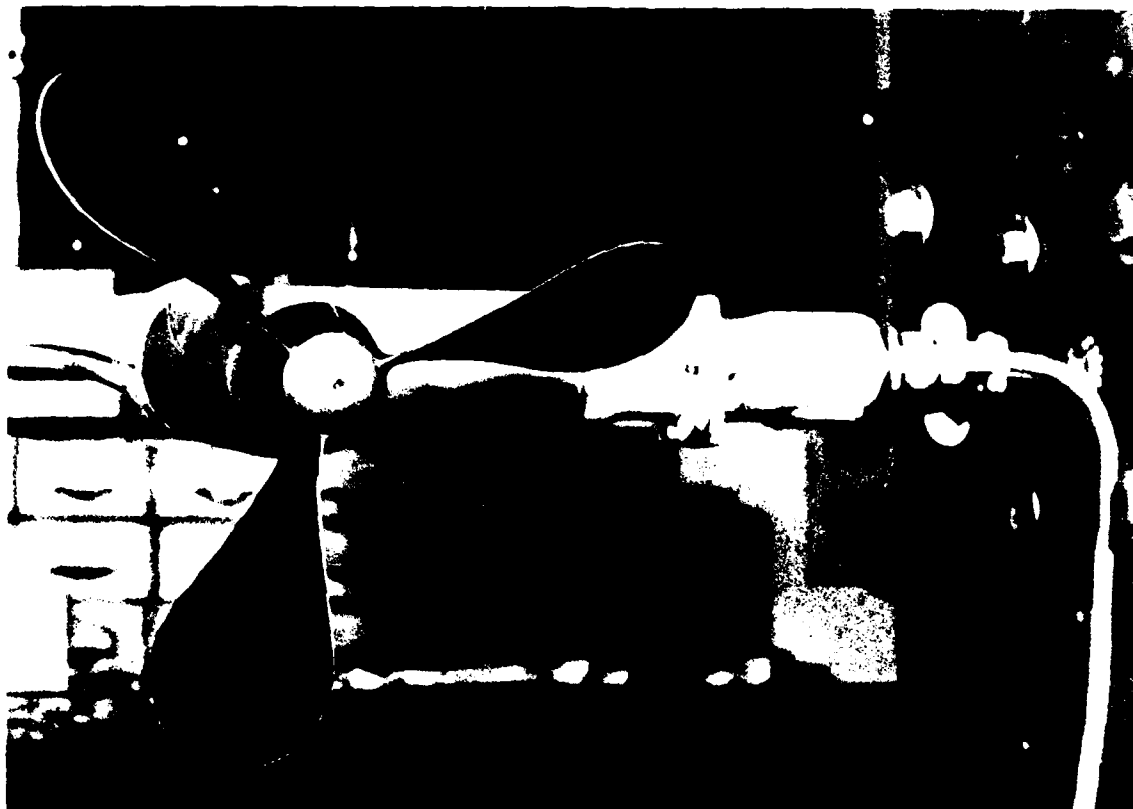


Fig. 2 The detector mounted on the LSM for Back and Top blows

was 185°, and speed indication was 10 knots. No damage was noted after either the 1-ft or 3-ft blows. The 5-ft blow caused considerable damage to the vane, as shown in Figs. 3 and 4 and listed below.

- (1) One of the rotor blades snapped off.
- (2) The center assembly section was bent and deformed (Fig. 4).
- (3) The tail section snapped off due to failure of the epoxy bond to the metal insert at its forward end, which remained bolted to the center assembly section.
- (4) In addition to the damage to the vane, the pintle bolt was bent slightly.

In spite of this damage, the speed and direction synchros appeared to function normally. Damage was repaired by:

- (1) Replacement of the rotor.
- (2) No action was taken.
- (3) Fastening the tail of the metal insert with four sheet-metal screws.
- (4) No action taken.

Following repairs, the unit functioned normally.

3.8.2. Top Blows - No changes are made in the test arrangement for this test direction -- Top blows are struck with the vertical rather than the swinging hammer. The reference wind accordingly remained at 185°, 10 kt. Once more, no damage was noted from the 1-ft or 3-ft blows. On the 5-ft blow, the molded GRP halves of the tail separated at the top seam (Fig. 5), and some minor cracking was noted in the GRP material just forward of the tail's stabilizer section. The seam separation was taped together with cellophane tape. The unit again functioned normally.

3.8.3. Edge Blows - Edge blows are struck with the swinging hammer after the anvil plate assembly has been rotated 90°, as shown in Fig. 6. In this arrangement, the reference wind direction indication was 190°, speed indication 7 kt.

No damage was noted for the 1-ft or 3-ft blows. Following the 5-ft blow, the two halves of the tail assembly were found to have separated completely, and the cracking noted earlier to have progressed (Fig. 7). A general looseness of the entire vane assembly was noted; when the detector was disassembled, it was found that this was due to the loosening of the nuts, bolts and screws connecting the rotor and tail sections to the center assembly section, and the direction synchro to the mounting. While this looseness may have degraded performance, the system still functioned.

3.9. Assessment of Shock Performance - The vane assembly constitutes the most serious problem area. The rotor itself may fail, and to ensure reliability it may be necessary to construct it of metal. The bonding of the tail section is totally inadequate, and the material itself subject to cracking; perhaps this could be cured by one-piece construction. The center assembly section must be more robust in order to resist the deformation observed. The nuts and bolts holding the vane assembly together must be reconfigured to prevent loosening. Each potential fix would appear likely to exacerbate another existing problem -- a metal rotor and one-piece tail

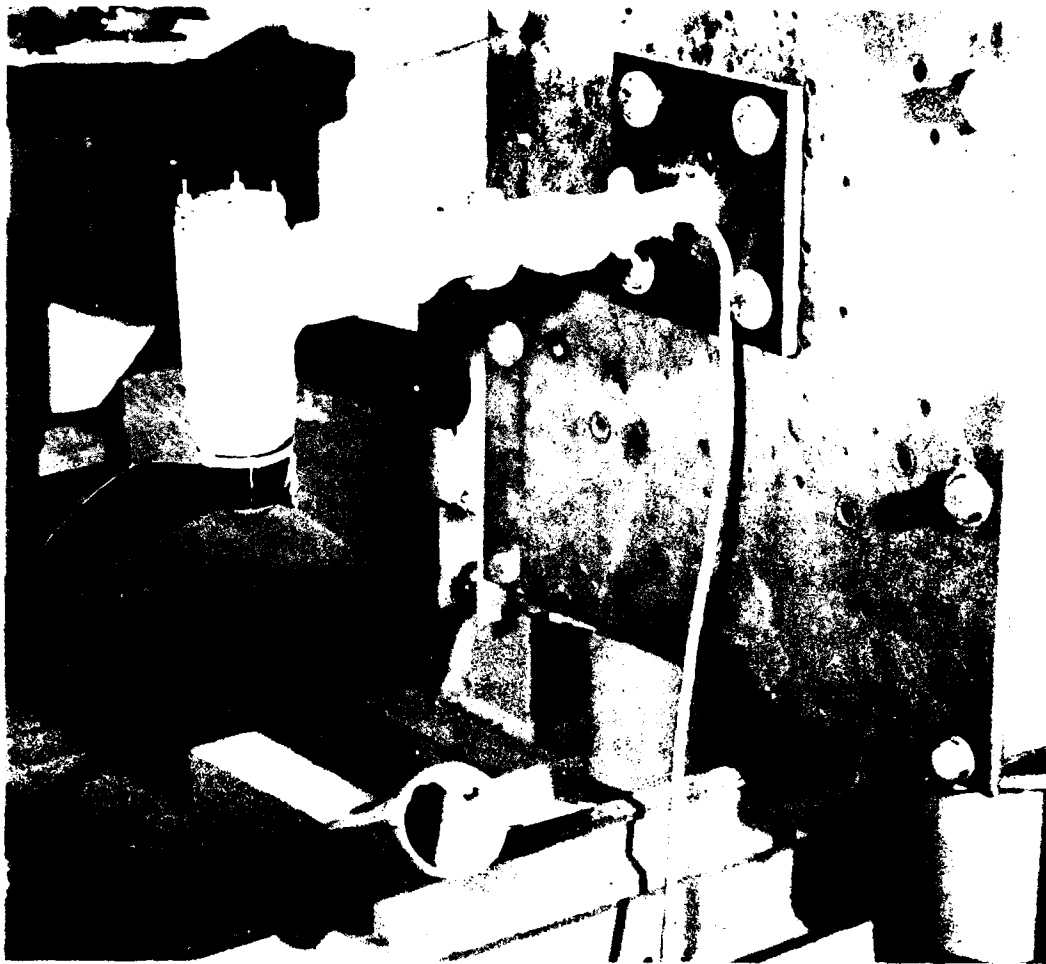


Fig. 3 The detector after the 5-ft Back blow. Note broken rotor blade and tail assembly

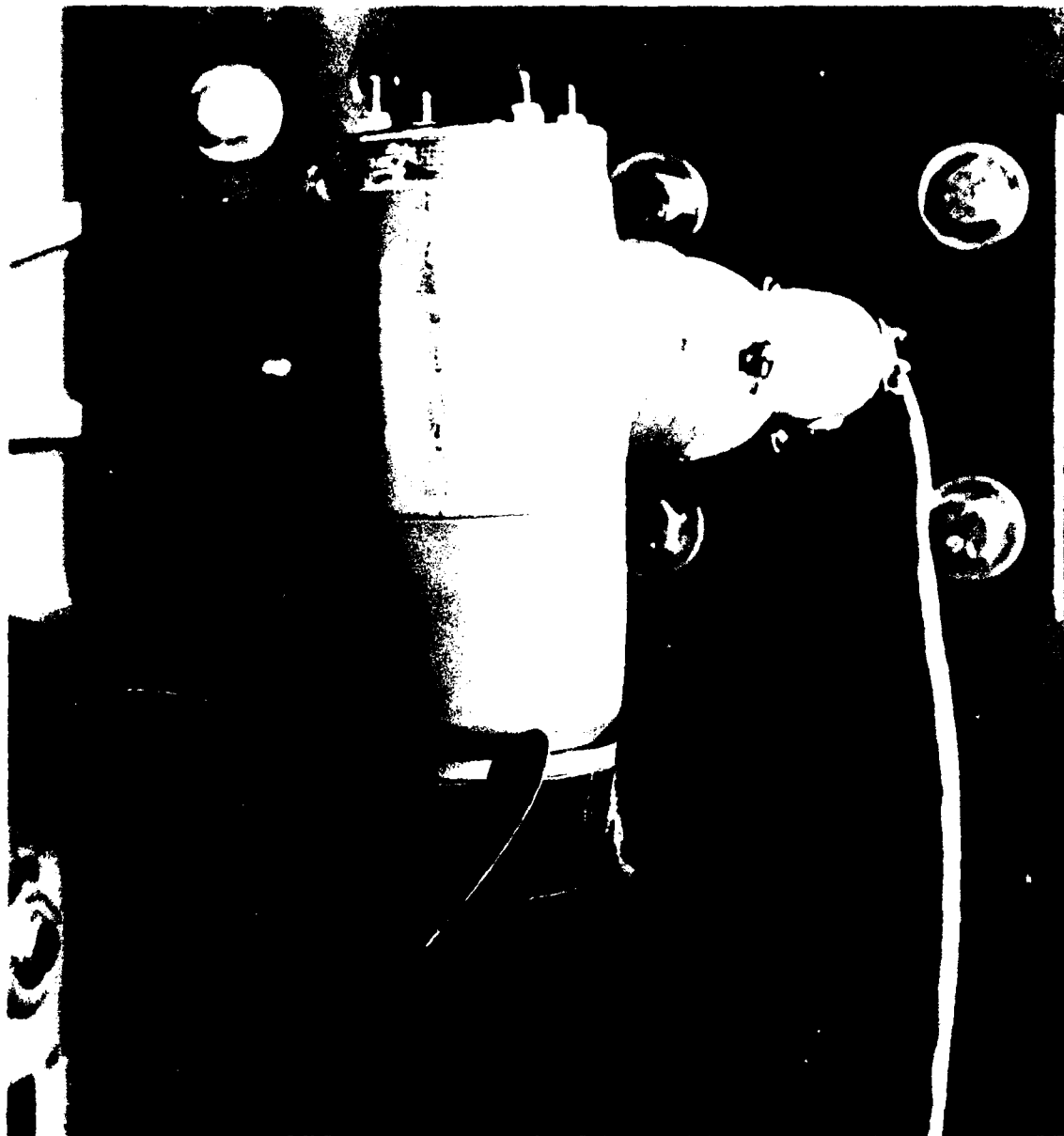


Fig. 4 — Damage to the detector from 5-ft Back blow. The metal insert of the tail assembly is still attached to the center assembly section, but the epoxy bond to the tail molding has failed. Note deformation of the center assembly section.



Fig. 5 — Damage to the detector from 5-ft Top blow. The epoxy bond holding the two halves of the tail assembly has failed.

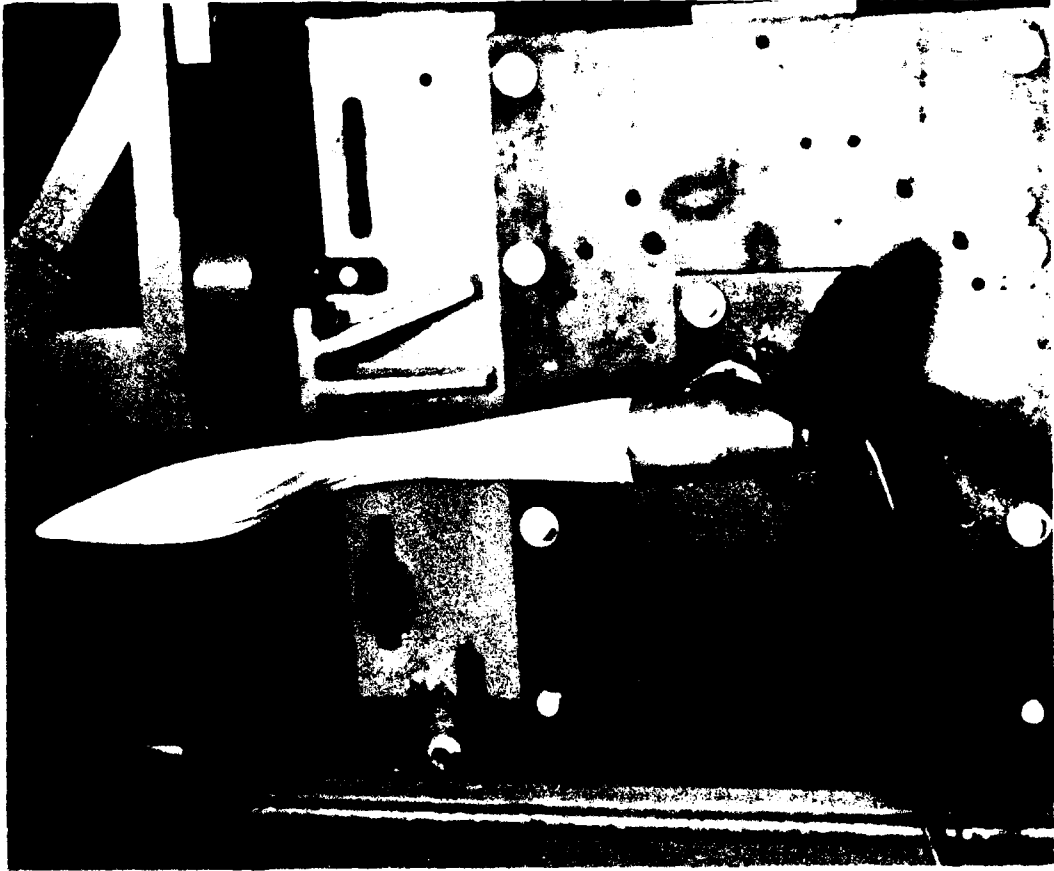


Fig. 6 — The detector mounted on the LWSM for Edge blows



Fig. 7 Damage to detector from 5-ft Edge blow. Note cracking of tail molding, and additional separation of the two halves.

section would be heavier, and require a still heavier center assembly section and more secure assembly fasteners. This will mean a vane assembly which is probably substantially heavier, and an attendant need to improve support structure and fasteners all down the line. Since the fasteners securing the direction synchro to the mounting loosened, these also require attention. Finally, the bending of the pintle bolt provides another indication that it is a potential problem, even though it remained intact.

4. Shock and Vibration Tests of the Type F Transmitter Unit.

4.1. For vibration tests, the transmitter was fastened to a 1/2-in steel plate attached to a Bulkhead Fixture on the RVM. This arrangement is shown in Fig. 8, oriented for vibration in the "horizontal-perpendicular-to-front" axis. Also shown is the detector, again exposed to a reference wind from a floor fan. For the vibration tests, the reference wind gave speed indication 7 kt, direction 0°.

4.2. Vibration Tests - Vertical.

4.2.1. Exploratory - The RVM was operated from 4-33 Hz at amplitude 0.010-in, and from 34-50 Hz at amplitudes 0.003-in. At 48 Hz, the speed indication increased by 2 knots. No other effect was observed.

4.2.2. Variable Frequency - The RVM was operated over the frequency range 4-46 Hz with amplitudes of 0.030 in, 4-15 Hz; 0.020 in, 16-25 Hz; 0.010 in, 26-33 Hz; 0.005 in, 33-40 Hz; and 0.003 in, 40-46 Hz. Vibration was sustained at each integral value of frequency for five minutes. No structural resonance or operational malfunction was noted, but the transmitter was noticeably noisier (as judged by ear) at 37 Hz than at other frequencies.

4.2.3. Endurance - The RVM was operated at 37 Hz, amplitude 0.005 in, for two hours. No malfunction or indication of damage was observed.

4.3. Vibration Tests - Horizontal-Parallel-to-Front.

4.3.1. Exploratory - The RVM was operated over the frequency range of 4-33 Hz at amplitude 0.010-in and 34-45 Hz at 0.003 in amplitude. The test frequency range was limited to 45 Hz by resonance of the Bulkhead Fixture, which renders it impossible to control the vibration amplitude presented to the test item with the required precision at higher frequencies. No resonance, malfunction or unusual behavior of the transmitter was observed.

4.3.2. Variable Frequency - The RVM was operated over the range 4-42 Hz with the following schedule of amplitudes: 0.030 in, 4-15 Hz; 0.020 in, 16-25 Hz; 0.010 in, 26-33 Hz; 0.005 in, 34-40 Hz; and 0.003 in, 40-42 Hz. Vibration was maintained for five minutes at each integral value of frequency. A slight increase in the transmitter's emitted noise was noted at 8 Hz; however, as in the vertical vibration, it sounded noisiest at 37 Hz. No damage or malfunction was evident.

4.3.3. Endurance - The RVM was operated at 37 Hz, amplitude 0.005 in for a period of two hours. Although no malfunction was noted, post-test inspection found considerable play, at some positions, between a spiral shaft

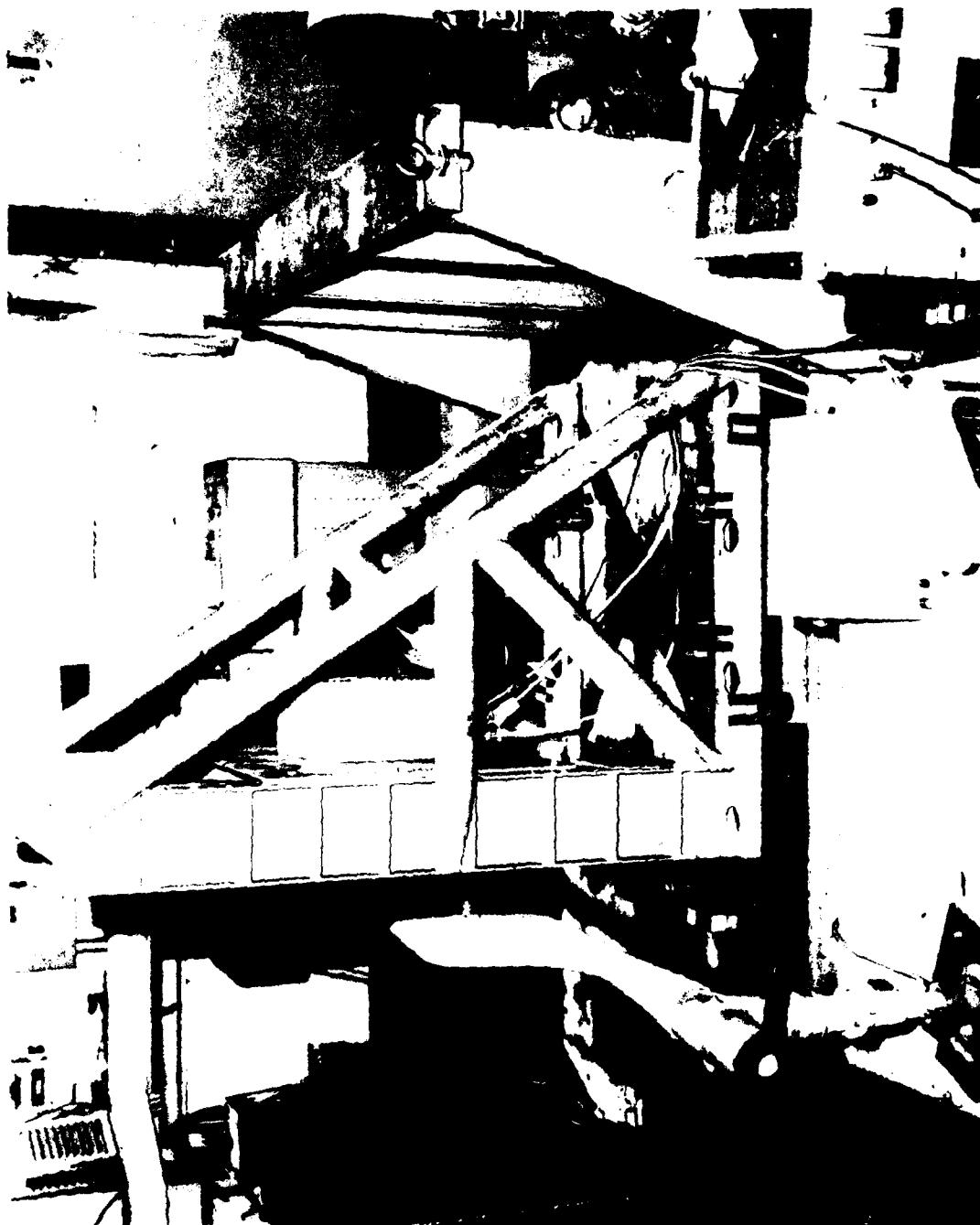


Fig. 8 — The transmitter mounted on the Bulkhead Fixture on the RVM, oriented for vibration along the Vertical and Horizontal-Perpendicular-to-Front axes

and pinion in the wind speed section. The affected parts were PC No 243A and PC No 246B. No other peculiarities were noted.

4.4. Vibration Test - Horizontal - Perpendicular-to-Front.

The Bulkhead Fixture, complete with transmitter and mounting plate, was unfastened from the RVM test-table and rotated 90°. The test arrangement for this axis is shown in Fig. 8.

4.4.1. Exploratory - The RVM was operated at amplitude 0. 4-33 Hz, and amplitude 0.003 in from 34-35 Hz. The frequency sweep was terminated at 35 Hz because of fixture resonance. The transmitter did not seem to be affected by this test in any way.

4.4.2. Variable Frequency - The RVM was operated over the range 4-33 Hz with the following schedule of amplitudes: 0.030 in, 4-15 Hz; 0.020 in, 16-25 Hz; 0.010 in, 26-33 Hz. At each integral value of frequency, vibration was sustained for five minutes. A resonance of the transmitter was encountered at 29 Hz, peaking at 32 Hz. At 31 Hz the speed indication dropped to 0 kt -- at 32 Hz it varied erratically from 0-90 kt. The test was terminated after 33 Hz to avoid problems from the fixture resonance at higher frequencies. Examination of the transmitter revealed that the speed range-limiting screws had backed out; the one preventing indications below 0 kt was loose, while that preventing indications over 100 kt had come out entirely. When these were replaced the system functioned normally.

4.4.3. Endurance - The RVM was operated at 32 Hz, amplitude 0.010 in, for two hours. No damage or misbehavior was observed.

4.5. Assessment of Vibration Performance - The only malfunction observed was due to loosened fasteners. The security of fasteners in general must be assured; this is particularly necessary in equipment, such as the transmitter, where there are many fasteners critical to its operation. Steps to restrain fasteners more securely may be as simple as adding a lock-nut, or even a punch-mark, but consideration needs to be given to what fasteners are likely to loosen, and how to improve their retention. The other noted peculiarity, the play in the spiral shaft and pinion is potentially serious although it caused no problems. This particular assembly should be reviewed with regard to its response to shock and vibration environments. Possibly additional support for the shaft would be indicated.

4.6. Shock Tests - The transmitter was next removed from the Bulkhead Fixture and mounted on the 4A plate of the LWSM. For the shock tests, the reference wind speed indication was 10 kt, and direction indication 30°. Figure 9 shows the test arrangement for Edge Blows.

4.6.1. Back Blows - Back blows of 1-ft, 3-ft and 5-ft drop-height caused no apparent damage or malfunction.

4.6.2. Top Blows - No effect was noted from the 1-ft blow. After the 3-ft blow the external monitors indicated malfunction of the wind speed section. Examination revealed that three gear retainers had loosened, one of them (associated with gear PC No. 271) enough to allow the gear to lose engagement. The others were associated with gears PC No. 274 and PC No. 246B. While this examination was in progress, it was observed that

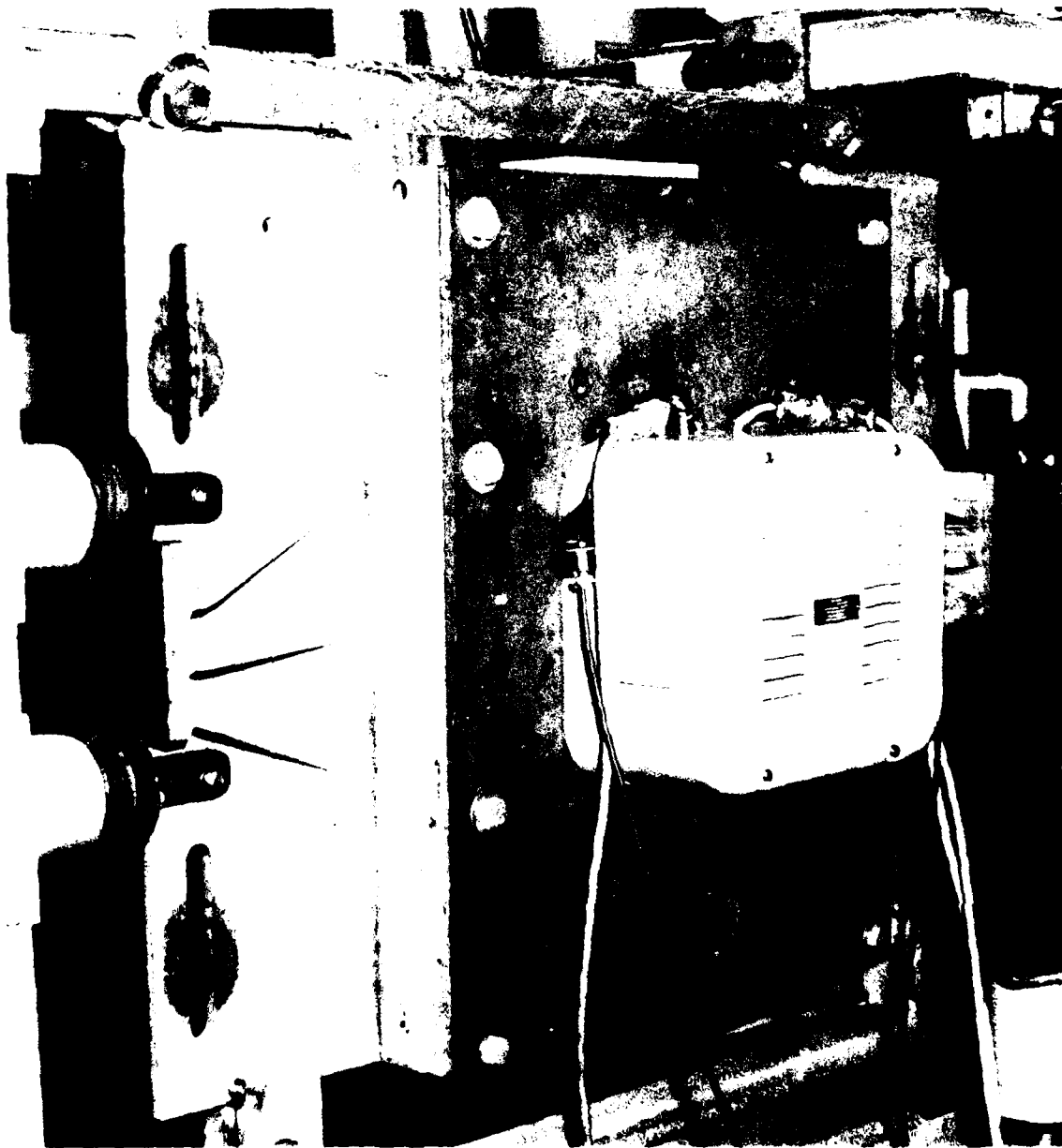


Fig. 9 - The transmitter mounted on the LWSM, oriented for Edge blows

the base plate of the transmitter had fractured at the mounting bolt on the center line of the top side (Fig. 10). Such a fracture would be most likely to occur under Back blows: it may in fact have been sustained during the Back blows, probably the 5-ft, and passed unnoticed until the two Top blows had opened it a little further. Since the fracture did not appear to extend completely through the base plate, and the remaining blows of the test schedule were Top and Edge, which would be less likely to extend it than the Back blows, the test was continued. When the shaft retainers had been replaced, the system functioned properly. The 5-ft blow had no apparent effect on operation or the fracture.

4.6.3. Edge Blows - No additional damage or malfunction was noted for 1-ft, 3-ft and 5-ft Edge blows.

4.7. Assessment of Shock Performance - The behavior of the shaft retainers is another example of the need for secure fasteners discussed above. The fracture of the base plate, which is an aluminum casting, would constitute a failure. Cast materials are generally discouraged or forbidden for shipboard installations because of their poor shock resistance. The low ductility typical of cast metals renders the extent to which a fracture will propagate unpredictable. In this case, the fracture remained minor; in the next, it could be catastrophic. Note also that even the minor fracture found here could, because of its location, have had considerable influence of the dynamics of the transmitter, and possibly on its performance under shock.

5. Shock and Vibration Tests of the Wind Speed and Direction Indicator, Type F/60.

5.1. For vibration tests of the indicator, a Bulkhead Fixture normally used with the Medium weight Shock Machine was employed. This has a much higher-frequency-resonance structure than the RVM Bulkhead Fixture. It is not used with the RVM because its size and weight permit it only for very small, light items, and because tests at these high frequencies are not usually needed. Also, rather than supplying reference signal from the detector and transmitter with a reference, floor-fan wind, the indicator was excited from a control and calibration box. Speed indication was set to 0 kt and direction indication to 0°. This was done for both shock and vibration tests. Figure 11 shows the test arrangement on the RVM for test in the Horizontal-Perpendicular-to-Front axis. The control box is shown in the foreground.

5.2. Vibration Test - Horizontal-Perpendicular-to-Front.

5.2.1. Exploratory - The RVM was operated from 4-33 Hz at amplitude 0.010 in, and from 34-47 Hz at amplitude 0.003 in. No resonances or abnormal indications were observed.

5.2.2. Variable Frequency - The RVM was operated from 4-47 Hz with the following amplitudes: 0.030 in, 4-15 Hz; 0.020 in, 16-25 Hz; 0.010 in, 26-33 Hz; 0.005 in, 34-40 Hz; and 0.003 in, 41-47 Hz. Vibration was sustained for five minutes at each integral value of frequency. No resonance or abnormal indication was observed.

5.2.3. Endurance - The RVM was operated at 47 Hz, amplitude 0.003 in,

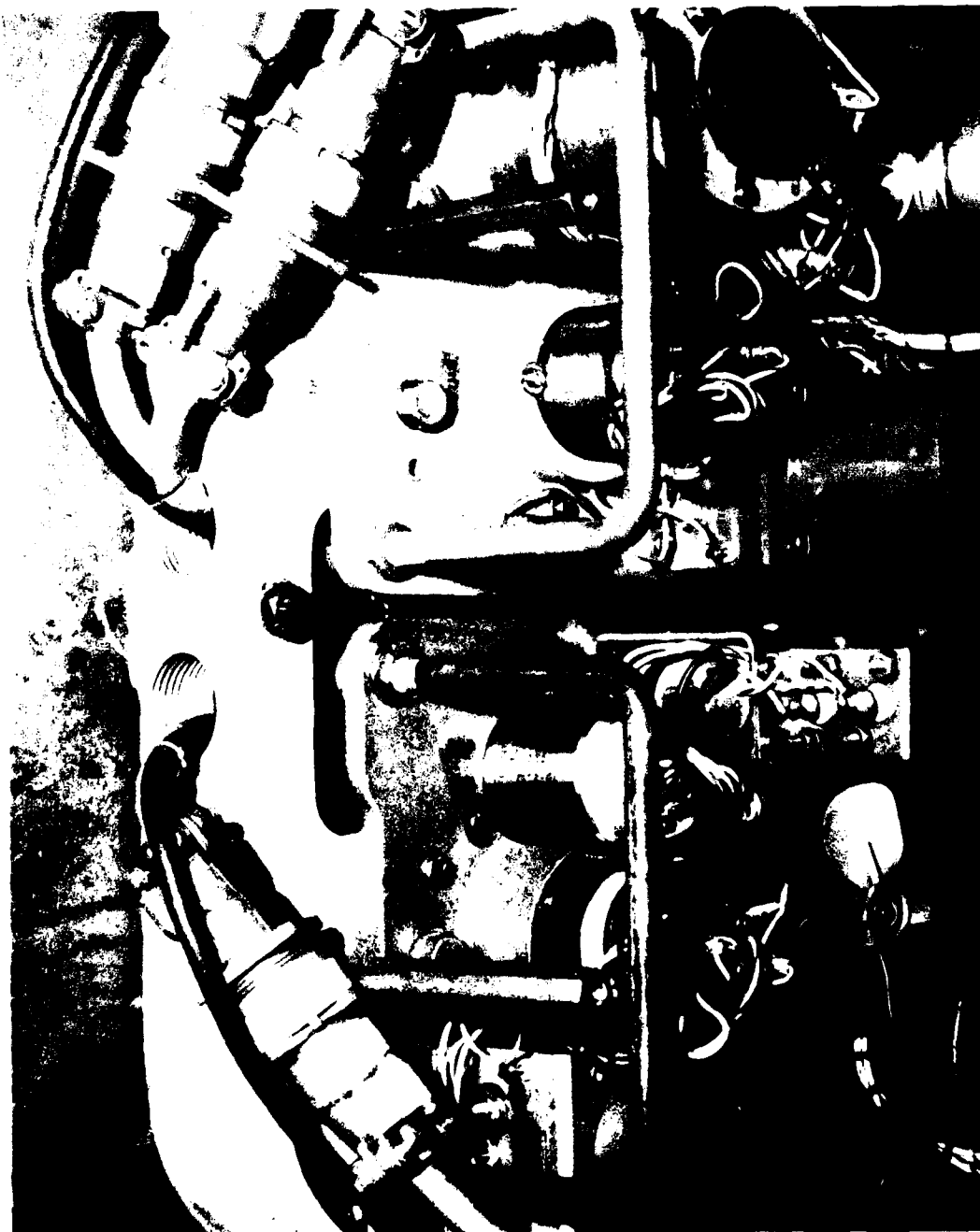


Fig. 10 — The fracture in the transmitter base plate found after the 3-ft Top blow. The fracture is located at the bolt at top-center, and progresses about half-way through the base plate. It may well have been initiated during the Back blows.



Fig. 11 — The indicator mounted on the MWSM Bulkhead Fixture on the RVM, oriented for vibration in the Horizontal-Perpendicular-to-Front axis. For shock and vibration tests, the indicator was excited from a calibration and control box, front center.

for two hours. No resonance or variation in indications was noted, and post-test examination did not reveal any perceptible damage.

5.3. Vibration Test - Horizontal-Parallel-to-Front.

5.3.1. Exploratory - The RVM was operated from 4-33 Hz at amplitude 0.010 in and from 34-33 Hz at amplitude 0.003 in. No effect on the indicator could be detected.

5.3.2. Variable Frequency - The RVM was operated from 4-44 Hz at the following amplitudes: 4-15 Hz, 0.030 in; 16-25 Hz, 0.020; 26-33 Hz, 0.010 in; 34-40 Hz, 0.005 in; and 41-44 Hz, 0.003 in. At each integral value of frequency, vibration was sustained for a five-minute period. No resonance was detected, and no effect on the indicator was observed.

5.3.3. Endurance - The RVM was operated for two hours at a frequency of 44 Hz and amplitude of 0.005 in. No effect on the indicator was observed, and no damage was detected on post-test examination.

5.4. Vibration Test - Vertical

5.4.1. Exploratory - The RVM was operated from 4-33 Hz at amplitude 0.010 in, and from 34-45 Hz at amplitude 0.003 in. No resonances were noted.

5.4.2. Variable Frequency - The RVM was operated from 4-45 Hz at amplitudes of 0.030 in (4-15 Hz), 0.020 in (16-25 Hz), 0.010 in (26-33 Hz), 0.005 in (34-40 Hz), and 0.003 in (40-45 Hz). No resonance was detected, and no effect on the indicator was noted.

5.4.3. Endurance - The RVM was operated at 45 Hz, amplitude 0.003 in, for two hours. No effect on the indicator was noted, and no damage was detected on examination after the test.

5.5. Assessment of Vibration Performance - The indicator behaved very well under vibration, showing no untoward effects either functionally or structurally.

5.6. Shock Test - The indicator was next mounted on the 4A-plate of the LWSM. Excitation was again supplied by the control and calibration box. The test arrangement for Back Blows is shown in Fig. 12.

5.6.1. Edge Blows - The 1-ft blow had no apparent effect. The direction indication changed from 0° to 350° during the 3-ft blow, while the speed indication was unaffected. The direction indication was reset to 0° , and on the 5-ft blow, changed to 345° . The speed indication was again unaffected. General operation, both speed and direction, was otherwise normal after the test.

5.6.2. Back Blows - On the 1-ft blow, the direction indication once more changed from 0° to 345° , while the speed indication remained at 0 kt. The direction indication was reset to 0° . During the 3-ft blow, the indicator became completely inoperative. Examination disclosed that the fasteners for both synchros had bent, allowing them to drop out of position and rotate freely. In addition, the speed synchro was inoperative:

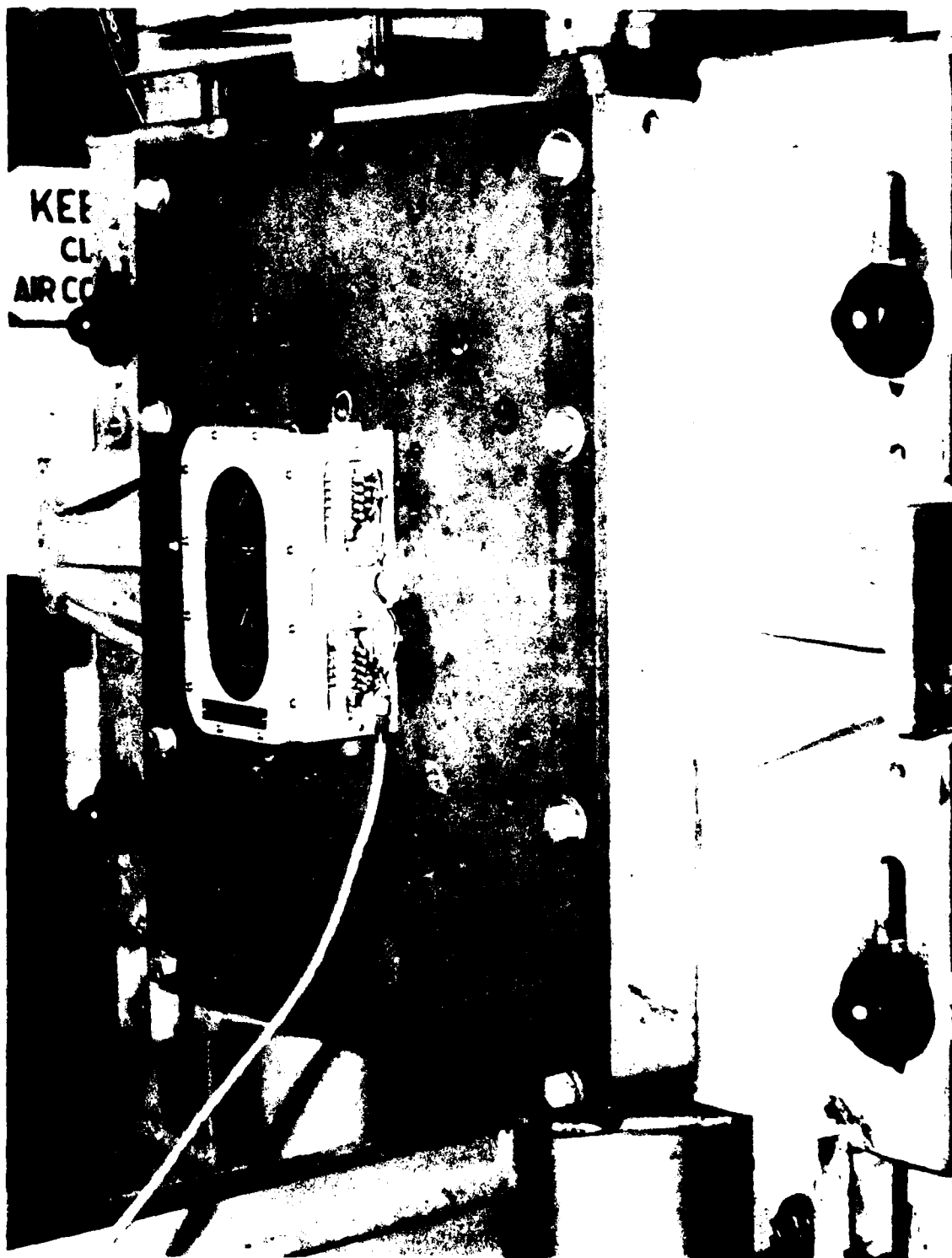


Fig. 12 — The indicator mounted on the LWSM, oriented for Back and Top blows

the reason unknown.

5.7. Assessment of Shock Performance - In contrast to its excellent vibration performance, the shock performance of the indicator was totally inadequate. Again, a major contributor was internal fasteners. The reason for the malfunction of the speed synchro is not at present known; tests at NAEC are expected to identify it. It too may be related to the failure of the fasteners to restrain the synchro properly.

6. Conclusions and Recommendations

6.1. Vibration tests of the Type F system have revealed deficiencies in two units (detector and transmitter). Shock tests reveal deficiencies in all three units. Internal fasteners are a generic weakness in all units. Structural problems involve the base plate of the transmitter and the vane of the detector.

6.2. The inadequacy of internal fasteners involves fasteners of all descriptions -- nuts and bolts, screws, shaft retainers, synchro clamps, etc. All must be reviewed with regard to dynamic loadings. Cures to be considered would include resizing, adding locking mechanisms, etc. Note that the clamping arrangement traditionally employed for installing synchros and servoes is inadequate for shock and vibration loadings, particularly with regard to screw size.

6.3. The structural problem with the transmitter base plate is one of material. Cast metals are essentially banned by shock requirements, and should be replaced by forged or machined assemblies wherever they occur. This applies also to those parts which did not misbehave during the tests described here. Cast materials simply cannot be relied upon in the shipboard shock environment.

6.4. The structural problems with the detector are all-encompassing. Starting from the bottom, the pintle-bolt should be enlarged as a precaution. The basic detector structure is a casting. The vane assembly must be completely redesigned to prevent destruction under shock excitation, and erroneous performance under vibration. It is not immediately apparent how this can be done without sacrificing some of the low-inertial quality desirable for rapid response. It seems that plastic parts should be replaced by metal, and metal parts made more robust. The tail assembly requires a more reliable bonding technique, or possibly a one-piece construction; additional redesign would probably still be necessary for it to survive the shock test.

6.5. The modifications and revisions suggested above are likely to be costly in terms of time and/or materials. Since the Type F system represents technology of some forty years ago, it may be more profitable to replace it, in whole or in part, with components exploiting current instrumentation and processing techniques. Approaches such as an array of hot-wire anemometers, or even Pitot tubes, with microprocessor-controlled calibration and data-conversion elements should be feasible. It is suggested that consideration should be given to developing more modern and more reliable hardware.

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